LCA Standardisation

A Comprehensive Approach Towards Product and Organisation Related Environmental Management Tools

Life Cycle Assessment (ISO 14040) and Environmental Management Systems (ISO 14001)

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Abstract

The international standardisation of Environmental Management (EM) is documented by the ISO 14000 series. Within this series a number of Environmental Management tools are treated. Therefore, it can be seen as a "toolbox" which offers several options for sound Environmental Management practices in organisations. However, a number of questions remain because they are not treated by the standards themselves. Some examples are which of the tools should be applied to what kind of Environmental Management problem or what are the synergisms and antagonisms between these tools. To illustrate the importance of a comprehensive choice and a compatible approach towards EM-tools, Life Cycle Assessment (ISO 14040 series) is discussed in the context of Environmental Management Systems (ISO 14001). The focus of ISO 14001 are organisations, while LCA deals with products or processes. In principle, they are not compatible, since the life-cycle approach analyses one production chain from "cradle to grave" or even back to the cradle, while a management system according to ISO 14001 analyses organisations, i.e. a number of product chains, from "gate to gate". LCAs, however, could be compiled by aggregating several "gate to gate" energy and material balances of companies. LCA can assist in prioritising and achieving the objectives of an EM-System. LCA can also help to understand the environmental impact of organisations and what share of their overall environmental burden is produced "inside the gates" or "outside the gates", respectively.

Keywords: EMS, environmental management systems, ISO 14001; environmental management systems (EMS), interfaces to LCA; environmental management systems (EMS), ISO 14001; LCA, ISO 14040; Life Cycle Assessment (LCA), interfaces to EMS; Life Cycle Assessment (LCA), ISO 14040

1 Introduction

Human use of many essential resources and the generation of many kinds of pollutants have already surpassed rates that are physically sustainable. Thus, changes in the behaviour and thinking of mankind are indispensable. These changes have to occur first in a comprehensive revision of policies and practices that perpetuate growth in material consumption and in population and, second, in a drastic increase of efficiency factors in connection with material and energy use [1].

The awareness of industry, politics and society concerning environmental problems has broadened by information about potential future impacts. Therefore, strategic corporate decisions within a company's policy are no longer based merely on technical and economical aspects. The environment is a factor of strongly growing importance [2].

Nowadays, companies dedicate a lot of financial and personal effort to the protection of the environment. They recognised the importance of building up confidence with all stakeholders (e.g. consumers, neighbours, associations, financial partners, public authorities, media, etc.) interested in these efforts. However, the approach of increasing the protection of the environment in a credible manner also means to make new choices in corporate decisions and therefore to take new risks.

In order to minimise risks companies need to rely on stable schemes to framework their approaches, which will have to be recognised as valid by the stakeholders. This is a core reason for the implementation of international standards, because they are based on the widest consensus of management tools, so that those companies that are committed to improve the environmental performance of their activities, products or services can be confident in their methods.

The international standardisation of Environmental Management (EM) is documented by the ISO 14000 series [3-5]. A number of Environmental Management tools are treated within this series. Therefore, it can be seen as a "toolbox" which offers several options for sound Environmental Management practices in organisations.

However, a number of questions remain because they are not treated by the standards themselves. Some examples are, which of the tools should be applied to what kind of Environmental Management problem or what are the synergisms and antagonisms between these tools.

In addition, the standards are developed as separate documents. Therefore, information about the interfaces and relationships between these tools, about their advantages and disadvantages is not available in the documents and has not yet been discussed in a systematic manner. To illustrate the importance of a comprehensive choice and a compatible approach towards EM-tools, Life Cycle Assessment (ISO 14040 series) [6-9] is discussed in the context of Environmental Management Systems (ISO 14001) [10].

2 Environmental Management Tools

The Environmental Management tools of the ISO 14000 series are briefly described in this section. They can be subdivided into organisation related and product/service related tools. An overview is shown in **Figure 1**.

Another distinction can be made between procedural tools and analytical tools. Environmental Management Systems (EMS) are a procedural tool, whereas LCA and the EMS-element Company Ecobalance (CEB) are analytical tools (→ *Section 3.1*).

2.1 Management tools for organisations

The Management tools for organisations which are treated by ISO 14000 are Environmental Management Systems (EMS), Environmental Auditing and Environmental Performance Evaluation (EPE).

2.1.1 Environmental Management Systems (ISO 14001)

This tool specifies requirements for an environmental management system to enable an organisation to formulate a policy and objectives taking into account legislative requirements and information about significant environmental impacts. The overall objective is a continual environmental improvement of the organisation.

System elements are Environmental Policy, Planning, Implementation and Operation, Checking and Corrective Action as well as Management Review [10]. There are similarities with the European Environmental Management and Audit Schema (EMAS) [11] and some structural similarities with Quality Management systems according to ISO 9000 [12-14]. If organisations fulfil the requirements of the standard, they can obtain a certificate from an accredited ISO 14001 registrar [15].

2.1.2 Environmental Auditing (ISO 14010f)

Environmental Auditing can be understood as a part of the Checking elements of EMS. The first standards aimed at the need for common rules for the internal or external auditing of an EMS. Principles and rules of conducting an audit and qualification criteria of the auditors have been established [16-18].

2.1.3 Environmental Performance Evaluation (ISO 14030f)

The objective of this tool is to provide guidelines for the choice, monitoring and control of environmental indicators representing the performance of a company. Environmental Performance Evaluation (EPE) is a part of the Performance Audit within EMS [19].

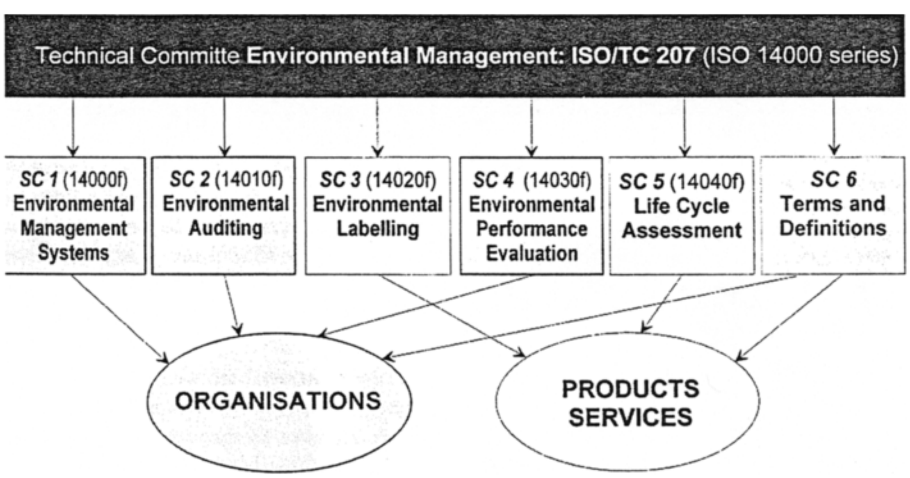

Fig. 1: Environmental Management tools (ISO 14000 series)

2.2 Management tools for products/services

The management tools for products/services which are treated by ISO 14000 are Life Cycle Assessment (LCA) and Environmental Labelling.

2.2.1 Life Cycle Assessment (ISO 14040f)

LCA is a tool to compile and evaluate the inputs and outputs and the potential environmental impacts of a product system throughout its life cycle. The system elements are Goal and Scope Definition, Inventory Analysis, Impact Assessment and Interpretation [6-9].

The applications of LCA are e.g. product development, product improvement, strategic planning, public policy making, marketing or environmental comparison of alternative products [20].

2.2.2 Environmental Labelling (ISO 14020f)

The ISO standards are considered as an adequate framework to defend a strict and rigorous approach for all types of ecolabels, thus limiting the risk of distorting effects to the market. The scope is the codification of ecolabels, providing standards to ground and improve self claims in their terminology, symbols and verification methods [21-26].

3 Interfaces between LCA and EMS

As described in the previous section LCA and EMS have different scopes. From a theoretical viewpoint LCA and EMS provide answers to quite different questions. While LCAs study products over the whole life cycle, Environmental Management systems aim at the continual improvement of organisations. There are three main aspects to achieve this goal: the dimension of legal requirements (Compliance Audit), the organisational dimension (System Audit) and the dimension of the environmental impacts (Performance Audit). LCA as a tool does not touch on legal or organisational aspects even though recommendations derived from the interpretation of LCA results often include organisational optimisation potentials. For an academic discussion of LCA and EMS, it is important to relate to these different aims.

However, from a practical and less structured viewpoint of the main users of both tools, i.e. companies, they might be seen to serve the same purpose in providing answers to the question, how the environmental performance of a company *and* their products can be improved. Companies and especially small and medium-sized enterprises cannot devote a large effort to an academic analysis of what type of tool could be used for what kind of problem. In addition, they will not use all of the EM-tools. Most of them will try to establish one common approach to achieve sound environmental management. To promote a broader use of the ISO 14000 series, a framework for a complementary approach shall be established.

As a starting point, the main interface between LCA and EMS, which is obviously the evaluation of the potential environmental impacts associated with the respective economic activities, is discussed. In the following sections the similarities and differences, the synergisms and antagonisms between measuring and evaluating potential environmental impacts by LCA and EMS will be discussed.

3.1 Input-/Output-Analysis of material and energy flows

To evaluate potential environmental impacts both tools are based on an input/output-analysis of physical flows of materials and energy. In an LCA, this is the Life Cycle Inventory Analysis (LCI), for EMS there is no specific term in the ISO 14001 standard. To make a clear distinction from LCA/LCI we suggest and use the expression Company Ecobalance (CEB).

3.1.1 System boundary

A main difference between LCI and CEB is the system boundaries. As schematically shown in Figure 2, the LCA system, i.e. the product system, consists of those processes of different companies which are necessary to produce the product under investigation (plus their use phase). Because this product system covers the whole life cycle of the product, LCA is often called a "cradle to grave" or even a "cradle to cradle" analysis.

A Company Ecobalance does not cover the life cycle of a product, but consists of all processes which take place at a company or at a particular production site of a company. Therefore, CEBs can be called a "gate to gate" analysis.

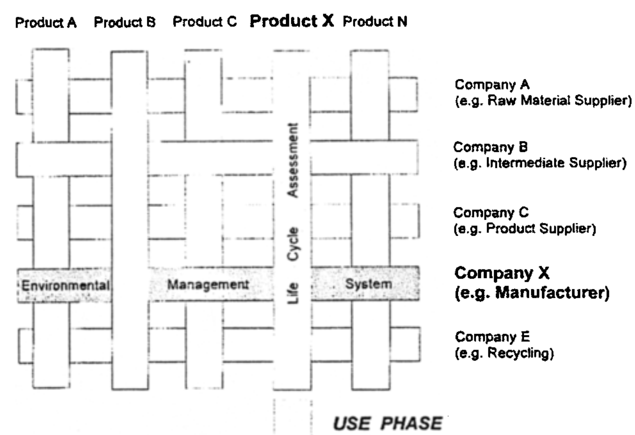

Fig. 2: Schematic Representation of the System Boundaries of EMS/CEB and LCA/LCI, modifed after [28,29]

However, most CEBs include transportation processes even though these processes are outside the system boundaries.

Figure 2 shows that the overlap between LCA and CEB is relatively small. For an LCA, a single CEB represents only one or a few life cycle stages, while a LCA covers only one or a few processes from the viewpoint of a CEB. In addition, LCA analyses the use phase of a product system. The different choice of system boundaries is of high practical relevance. This will be demonstrated by an example of four concepts for automotive clear-coat systems. The data for this example have been derived from an LCA study and have been published (e.g. SAE Total Life Cycle Conference 1997) [27].

Figure 3 shows the primary energy demand of the paint production, the application, the use phase and the disposal of the clear coat layer of a medium-sized car. Solventborne (1K and 2K) and waterborne clear coat is compared with powder clear coat. If a car producer with an Environmental Management System performs a CEB, only the data for the application step enters the ecobalance. As indicated in **Figure 3**, powder clear coat has the lowest energy demand for application only. However, if the scope is expanded towards the life cycles (incl. material production and use phase) of the alternative clear coat systems, powder clear coat leads to the highest energy demand. This example demonstrates that CEB and LCA can lead to different recommendations for the decision-maker, because of the definition of system boundaries. It should be stressed that **Figure 3** represents only one scenario which cannot be generalised to compare painting technologies (for details refer to [27]).

It should be noted again that LCA and CEB, in principal, have different scopes. However, in practice they are often used for the same purpose. If the car producer in the example devoted large efforts to implement an EMS, the management will use the information of the CEB. In general, they won't undertake yet another exercise – in this case an LCA – even if this might be more appropriate from a scientific point of view. To tackle this problem, a complementary approach has to be established that reduces the overall environmental management effort for companies. The recommendation to supplement any EMS by a number of LCAs is not promising.

3.1.2 Reference unit

Another difference between an LCA and a CEB are the respective reference units. In both methods, the input/output flows of material and energy are normalised to a reference unit. For Company Ecobalances, the reference unit is normally a certain period of time (e.g. one financial year). In LCA studies, the reference unit is the so-called functional unit or, in comparison, the functional equivalence of the alternatives. Therefore, the unit and the order of magnitude of LCA and CEB results are different.

Again, the relevance of this aspect is illustratively demonstrated by an example (compare **Figure 4**). In **Figure 4** two product systems of the same production chain are shown. It is assumed, that the company produces one product only. In the upper part it is assumed that all processes of a life cycle (incl. Process X) are within one company. Therefore,

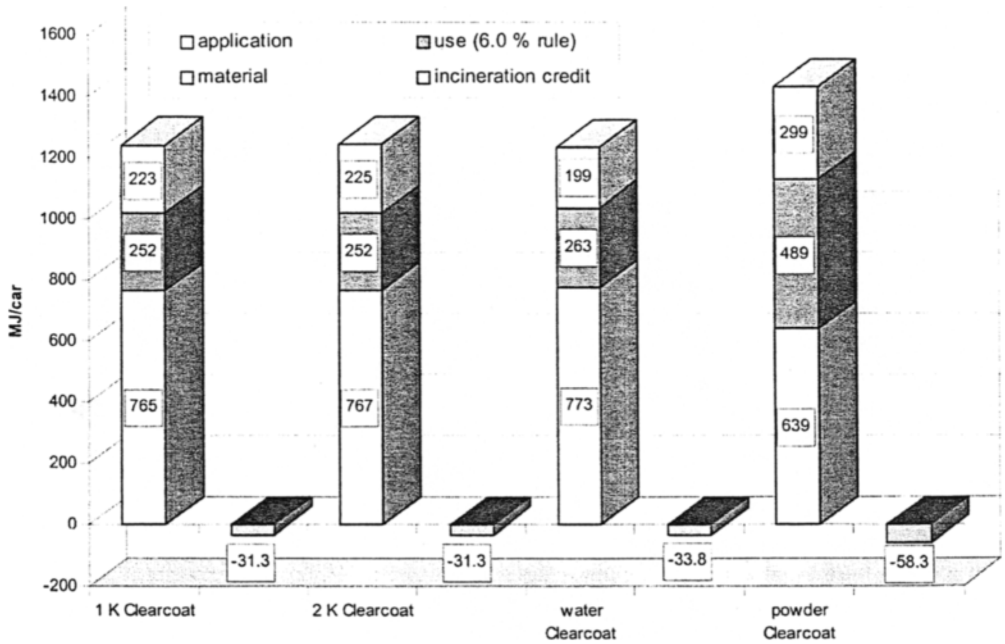

Fig. 3: Primary Energy Demand of Automative Clearcoat System

as indicated by the diagram the results for the environmental performance measured by LCA and CEB are the same.

In the lower part of **Figure 4** a product system in which Process X is an external process is assumed. Therefore, the CEB result is lowered as the reference are the flows within a company over a certain period of time. The LCA results do not change, because all processes which are necessary to fulfill the technical function of the studied object (measured by the functional unit) are included.

This simplified example shows, that CEB results are sensitive to the actual location of a process. The environmental performance of a company measured by a standard CEB is getting better, if an internal process is externalised, e.g. by outsourcing. This is methodologically consistent with the respective tools as LCA assesses the life cycle of a product while CEB is assessing the individual company. However, from a general viewpoint of sound environmental management it is clear that the potential environmental impact of an identical Process X is independent of the company who runs the process.

3.1.3 Allocation

Another methodological aspect which shows a distinct difference between LCA and CEB is the allocation problem [28,29]. The allocation question, i.e. the partitioning of environmental burdens in multi-input- or multi-output-processes, is one of the major methodological problems inherent in the type of question answered by LCA, which is not encountered or avoided in a CEB.

As a classical example the chlor-alkali electrolysis can be discussed. For a LCA of a product for which only one of the electrolysis products is needed, e.g. chlorine, the overall environmental burden of the electrolysis process has to be assigned to chlorine. There is no single solution to that problem as either mass, energy content, market prices etc. could be used to solve the allocation problem. However, ISO 14041 and 14049 give some guidance to choose between allocation procedures [7,30].

In Company Ecobalances this problem does not occur, because multi-input- and multi-output-processes are considered as a whole [28,29].

3.1.4 Data and parameters

From a practical and economical point of view it is desirable that CEB data could be used for LCAs, i.e. LCAs could be compiled by aggregating several "gate to gate" energy and material balances of companies and vice versa. At first glance there is no point, why this should not be feasible. However, in today's LCAs and CEBs the parameters and data used are somewhat different.

The parameters which are relevant for a LCA are flows which cross the border between technosphere and ecosphere. They are called elementary flows respectively product flows. As a consequence of the life cycle concept the elementary flows consist of resources on the input-side and emissions on the output-side only. All intermediate products are followed back to their origin, i.e. the intermediate flows are

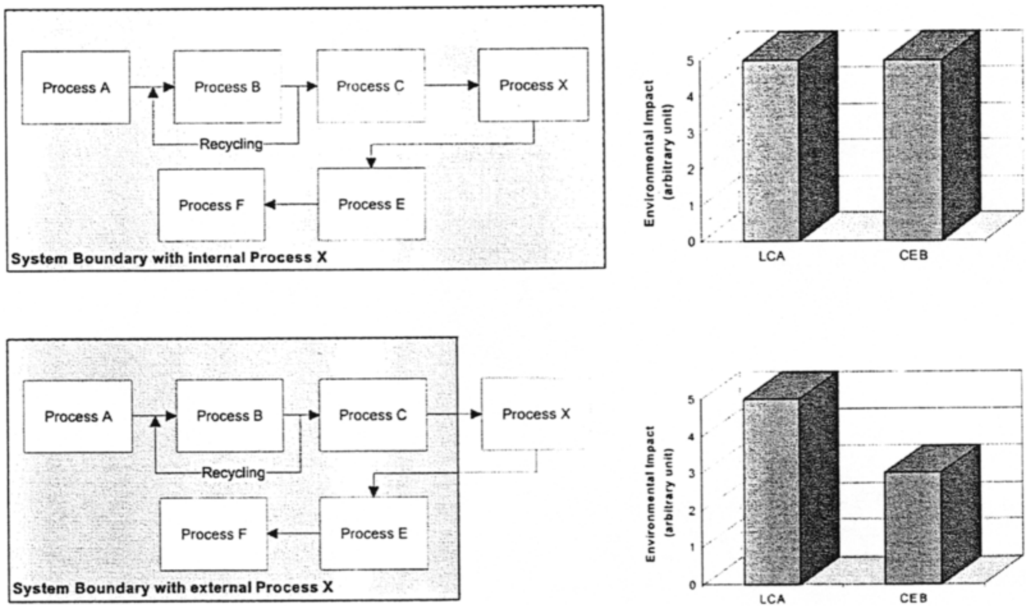

Fig. 4: Influence of the Reference System on LCA-/CEB-results

completely within the technosphere and therefore inputs and outputs of processes but not of the final LCI.

In EMS the flows which enter and leave an organisation are relevant. Therefore intermediates are found in the input-/output scheme of CEBs. CEBs require data on the full magnitude of the processes.

Another difference in the parameters studied are stocks. In a classical LCA all processes are assumed to operate at a steady-state-level and at regular operation conditions. Only the allocated net inputs and outputs are used to calculate the LCI. In a CEB the stocks of materials and the consumption due to non-regular-operations are considered. As the storage of chemicals has a considerable environmental risk potential, CEBs deliver more information on that aspect than LCAs.

Apart from the parameters themselves the data to quantify the parameters have a different type, too. This can be demonstrated by **Figure 5** which shows LCA-/CEB-results for the primary energy demand of the production (compounding) of 1 kg of paint. Again, we are aware that CEB and LCA answer different questions. Yet, the studied paint producer used the respective information for the same purpose of optimising the production process.

The LCA-results for two types of paint were compiled according to ISO 14040 methodology including intermediate and raw material production. For the CEB results for 1 kg paint an EMS-indicator of the paint producer could be used, which measures the specific energy demand per kg paint by dividing the energy demand of the CEB to the amount of paint produced. The raw data are from the same paint producer.

The small diagram inserted in **Figure 5** shows the LCA-results for the complete life cycle divided into the modules raw materials, transport and compounding as well as the CEB-result (compunding step). It is expected that by adding the energy demand of further life cycle stages the result of the LCA is higher than the CEB. It is revealed that by far the largest share of the environmental burden is produced outside the factory gates of the paint producer, i.e. the CEB-

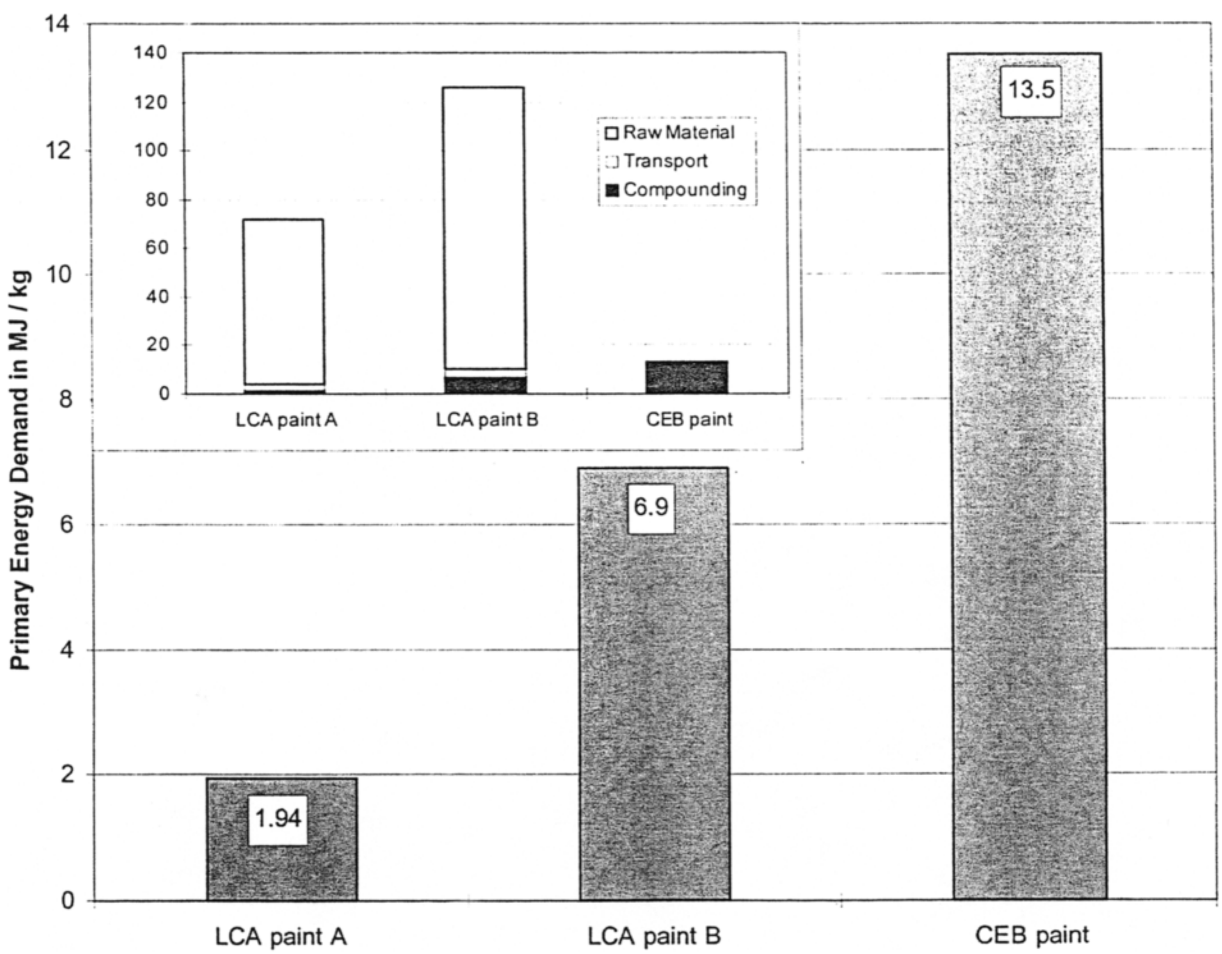

Fig. 5: Influence of different Data Types on LCA-/CEB-results

results which only account for the compounding step describe 5% to 15% of the potential environmental burden. Therefore, a large optimisation potential for the paint producer is the choice of the raw materials. This information is only obtained by LCA.

The main diagram in **Figure 5** examines the results of the compounding step in more detail. The primary energy demand for compounding according to the CEB is higher than both of the LCA-results. This can be explained by the different data types used to quantify the respective parameters. For the LCAs paint specific energy data of steady state operation are used. The CEB data represent the overall energy demand. The main difference is the energy consumption for business sectors like administration or research and development or room heating which are included in the CEB but not accounted for in a LCA. To neglect this data within an LCA is a convention, in principal not inherent to the tool. However, to include this information in an LCA would lead to significant allocation problems.

An advantage of the LCA-results is that different types of paint can be compared. In the examples of **Figure 5** the energy demands for paint A and paint B differ by a factor of 3. The CEB yields only an average energy demand for an average kg of paint.

3.2 Evaluation of environmental impacts and environmental costs

Apart from the input-/output-analysis of physical flows of materials and energy both potential environmental impacts and costs can be evaluated by EMS and LCA. A detailed discussion of these topics goes beyond the scope of this paper. In the following sections some main features of the respective elements will be described.

3.2.1 Environmental impacts

In EMS the evaluation of environmental impacts is called Environmental Performance Evaluation (EPE), in LCA this step is performed by Life Cycle Impact Assessment (LCIA).

EPE is an internal process and tool designed to provide management with reliable information to determine if the goals and criteria set by the EMS are met. EPE generally uses indicators like Environmental Performance Indicators (EPIs) and Environmental Condition Indicators (ECIs).

EPIs can be divided into Management EPIs (e.g. number of environmental training programs) and Operations EPIs (e.g. kg of contaminant X emitted per unit of production). The interface with LCA is closer with Operations EPIs. Their nature can be absolute (e.g. total energy demand per year), relative (e.g. energy demand per product), normalised (e.g. energy demand as a percentage of a baseline year), qualitative, aggregated or weighted. ECIs reflect local/regional conditions that are influenced by the company.

LCIA is defined as a quantitative and/or qualitative process to identify, characterise and assess the potential impacts of the environmental interventions identified in the LCI [31]. It consists of the steps classification, characterisation, normalisation and valuation.

The main difference between EPE and LCIA is the reference system. The reference system of EPE are goals which are set by the organisation itself, i.e. each organisation defines its own reference system, while LCIA refers to an reference system of safeguard subjects like human health, ecological health or resources, i.e. different LC(I)As relate to the same goals.

However, it should be stressed that there are several LCIA-methods and still debates about a generally accepted LCIA-methodology and reference system. So currently, the above statement about LCA represents not yet reality but rather a future perspective.

An interesting question is which "measurement" – LCIA or EPE – leads to a better effectivity and higher efficiency of the deducted measures to reduce environmental interventions. A disadvantage of EPIs and individual goals is the fact, that the targets are more subjective and the relevance of the targets measured by an respective EPI might be rather low. The paint producer of the example of **Figure 5** used an energy related EPI to achieve a reduction of the energy demand by 15%. This is a reasonable goal at first glance. However, it is not very relevant because the overall environmental burden is only reduced by 2% - 3%. If the effort to achieve this would be used to choose energetically superior raw materials the benefit for the environment could be much larger. In that respect, LCIA results are more objective and by including further life cycle stages the deducted targets tend to be more relevant.

On the other hand, the advantage of EPIs is that they are more direct and oriented on standard management practice. Therefore, once goals are set there is a high probability of achieving them, while LCA-results are indirect or even abstract and normally have to be "translated" before they can lead to environmentally motivated actions.

Finally, an advantage of EPE is that the full magnitude of processes is considered. Therefore, changes to the actual location of the processes can be measured.

3.2.2 Environmental costs

The evaluation of environmental costs is of steadily growing importance both for companies and authorities. Environmental costs can be subdivided into two main groups:

Internal costs, which reflect the principle that the organisation/person responsible for a negative environmental effect must bear the cost. Examples are costs for the investment and use of end-of-the pipe-technologies due to legal emission standards or environmental taxes.

External costs, which are not covered by organisations but by society. An example are costs due to increasing acidification or greenhouse warming (in the absence of a greenhouse or acidification tax).

The main difference between EMS and LCA is the fact that environmental costs, which are treated by an EMS, are necessarily internal costs, while LCA offers the opportunity to evaluate Life Cycle Costs [32] including external costs.

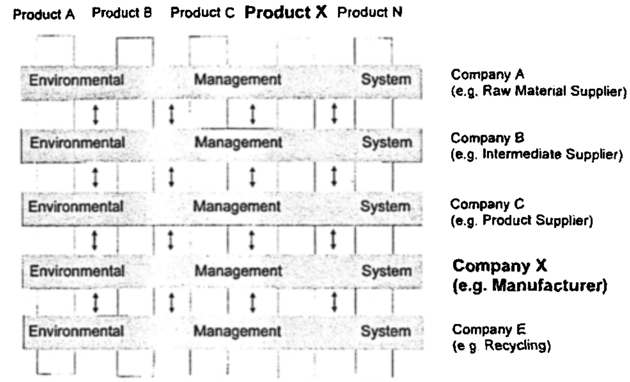

Fig. 6: Integration of LCA into EMS

4 Combination/Integration of LCA and EMS

In the previous section the interfaces between LCA and EMS were discussed. This discussion revealed that these tools are in principle not compatible, largely due to the fact that the life-cycle approach analyses one production chain from "cradle to grave" or even back to the cradle, while a management system according to ISO 14001 analyses a number of product chains from "gate to gate".

This illustrates the importance of a comprehensive choice and a complementary approach towards EM-tools as both tools aim to answer different questions, even though companies use both tools for the same purpose of optimising their environmental performance. There are two principal ways to benefit from both concepts:

Integration of LCA and EMS, i.e. using one tool but expanding the scope so that the main features of the other tool are included.

Combination of LCA and EMS, i.e. using both tools in a systematic, coherent way depending on the individual situation at the organisation respectively the main environmental management problems.

4.1 Integration of LCA and EMS

For the integration of the tools two approaches can be conceived. An approach which integrates LCA into EMS and vice versa.

4.1.1 Integration of LCA into EMS

Following the schematic representation of **Figure 2** a graphical illustration of integrating LCA into EMS is shown in **Figure 6**. The ideal of this concept would be, that all companies which are involved in the life cycles of all the products of a certain Company X have an EMS.

The scope of EMS is expanded along the life cycle of the products produced. The effectiveness of this approach is largely determined by the communication and cooperation of the companies in one product chain. By cooperating, their individual EM-systems can be put in a greater context and individual improvements could be directed towards an overall optimisation.

However, the main problem of this organisation based approach remains, because such an EMS-network can not guarantee that the products manufactured are environmentally superior to the products of a manufacturer without any EMS [28,29]. In addition, the practicability is questionable, because the choice and the negotiations with suppliers would generally result in a high amount of transaction costs. However, as shown by Udo de Haes and de Snoo [28,29] for the case of farmers and retailers, transaction costs need not necessarily prevent this approach.

4.1.2 Integration of EMS into LCA

A possible scheme for integrating EMS into LCA is shown by **Figure 7**. The ideal of this concept would be, that for all products of a certain Company X LCAs are conducted. Therefore, like in an EMS approach the whole organisation is considered, i.e. the scope of LCA is expanded towards the whole organisation. A similar concept by Taylor & Postlethwaite, which does not include different LCAs for all products, but one LCA for the functioning of an organisation as functional unit, was called Overall Business Impact Assessment [33].

The main problem of these concepts is that they do not evaluate comprehensive organisational information. Procedural elements like the goal to achieve continual improvement of the company are missing. Therefore, environmental goals on the company level might not be achieved due to the focus on single products. In addition, the concept of conducting LCAs for all products would require an enormous effort of Company X. This is another difference to

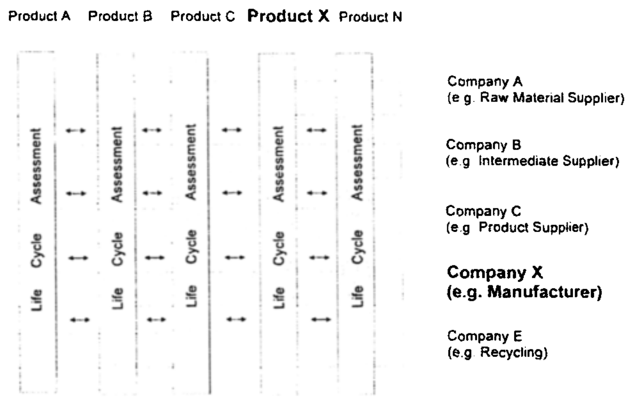

Fig. 7: Integration of EMS into LCA

the EMS-network where the efforts are shared between several companies.

4.2 Combination of LCA and EMS

The previous section showed that there are concepts to integrate the analytical tool LCA into the procedural tool EMS. The weaknesses of these concepts have been discussed. Because both conducting an LCA and implementing an EMS require already significant efforts, the expenditures expected for a strictly integrative approach might be a too large barrier for practical relevance. The solution could be a company/problem oriented combination of LCA and EMS.

According to this approach an organisation decides to primarily apply either LCA or EMS and as a second step complements it in a problem oriented way with the other tool. If a company decides to develop environmental management by implementing an EMS, LCA as a complementary tool could assist in a number of ways:

- LCA can complement the organisation oriented, procedural EMS-tool by investigating main or environmentally relevant products.
- LCA can assist in prioritising the objectives of an EMS.
- LCA can assist in achieving the objectives of an EM-System by a detailed weak-point-analysis of the production process.
- LCA can help to add objective and scientific elements to EPE
- LCA can reveal what share of the overall environmental burden of an organisation is produced "inside the gates" respectively "outside the gates".
- LCA can consider the use phase of products, which often is the life cycle stage with the highest relevance.
- LCA can assist Design-for-Environment
- LCA can assist supplier audits and choice of materials.
- LCA can assist investment decisions.

If an organisation starts environmental activities by conducting LCAs, it would benefit from complementary elements of an EMS, because:

- EMS can complement the product/ service oriented, analytical LCA-tool by procedural elements like organising main or environmentally relevant business sectors.
- EMS can help to realise the recommendations drawn from LCAs.
- EMS can assist in achieving an optimisation on a company level, rather than an optimisation of single products.
- EMS can assist in meeting legal requirements.
- EMS can assist in involving decision-makers.
- EMS involves more employees than the "LCA-specialists" and can help to promote corporate identity.
- EMS focusses on continual improvement.

The decision which tool should primarily be applied depends on the individual situation of the company and the main environmental problems of the company. Therefore, this decision has to be made company by company. However, in general it might be advisable for a company with a wide product spectrum to start with EMS, while companies with fewer products or single products with a high environmental relevance might start with LCA. This case by case procedure applies to the choice of complementary elements of the assisting tool as well. If a company, starting with LCA, faces problems meeting environmental standards, the EMS-element compliance audit might be first choice. A company with an EMS would conduct a first LCA for the main or the most relevant product.

In a cost/benefit-perspective this combination approach seems most effective, because it concentrates on and allows individual solutions. The PE-methodology for Weakpoint-Analysis and Optimisation by Life-Cycle-Engineering is a first step towards a feasible combination approach [34].

Finally, it seems important that both environmental managers within companies and their consultants have a strong background of both tools. This could increase the environmental and economical efficiency of these tools by promoting their synergisms and compensating their weaknesses. The sometimes formal or even bureaucratic approach towards EMS could be inspired and enlivened by life cycle thinking, while theoretical or even technocratic tendencies in LCA could be broken up for communication and decision oriented aspects.

5 Conclusions

Both Life Cycle Assessment and Environmental Management Systems are valuable tools for improving the environmental performance of organisations. Due to the company oriented, procedural approach of EMS and the product ori-

ented, analytical concept of LCA they are methodologically not compatible, even if at first sight similar system elements like the input-/output-analysis of material and energy flows are compared. The integration of the analytical EMS-element CEB into LCA might be theoretically possible, but practical relevance is questionable due to different system boundaries, different reference units, parameters and data. A promising solution might be a company/situation dependent combination of LCA and EMS. A sensible and comprehensive combination of complementary elements might increase the effectivity and the efficiency of environmental management efforts towards ecological and economical sustainability.

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